THE EXPLOSIVES ENGINEER

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Forerunner of Progress in Mining, Quarrying, Construction

Tecolote Tunnel, in the Santa Ynez Mountain 9 miles northwest of Santa Barbara, California, is listed in construction records as one of the toughest, most difficult tunnels ever driven. After the heading was advanced 8,940 ft. into the mountain ridge with no unusual happenings, the underground working area was suddenly transformed into what workmen termed "a snarling, vicious, fighting tiger." A tremendous inrush of water and sand through the heading in January, 1951, stopped all activities inside the bore.

After 40 long months of slow, laborious operations, the tunnel advance was halted a second time in July, 1953, because of increasing heavy flows of water, bad ground, and a temperature rise at the heading from 87 degrees Fahrenheit to 112 degrees. Tecolote Tunnel had stopped both the contractor and his men.

But the Bureau of Reclamation, sponsors of the project, had to hang on. A board of engineers, selected by the Bureau, recommended completion of the tunnel at any cost. Coker Construction Company and Peter Kiewit Sons' Company agreed to take over the work on a joint-venture subcontract basis. The Coker-Kiewit organization moved onto the job in January, 1954 .

A summary of how a combination of construction experience, veteran crews, and engineering skill of a high order made possible the completion of the tunnel one year later is presented on page 40.

° ° °

For some years, Constitution Boulevard, a two-lane highway connecting the towns of South Heights and Aliquippa in western Pennsylvania, had been a headache to the motoring public and the Commonwealth of Pennsylvania. In places, steep cliffs of deteriorating sandstone and shale overhung the boulevard, and rock and earth slides onto the boulevard were an ever-present danger.

In October, 1954, the Commonwealth received bids for the construction of a modern four-lane highway. The contract was awarded to Nello L. Teer Company of Durham, North Carolina, the low bidder, and work on the new highway was started in January, 1955.

The project involved unusually difficult grading and draining problems. Deep cuts had to be made through a sidehill approximately 2½ miles long. Close to 2,230,000 cu. yd. of rock and sandstone had to be blasted and moved away. In addition to working in rough, rocky terrain, the contractor had to maintain uninterrupted traffic on the boulevard alongside the job site and avoid damage to abutting railroad tracks and a steel plant.

For a description of the blasting details and rock-removal procedure, please turn to page 48.

° ° °

Completion of Table Rock Dam on the White River at a location 6 miles west of Branson, Missouri, and 10 miles from the Arkansas line will help to control flood waters and provide facilities for more and cheaper power in the Missouri-Arkansas-Oklahoma Ozarks.

Project specifications for the $78,000,000 dam, scheduled to be completed in July, 1958, call for an overall length at the top of 6,423 ft., of which 1,602 ft. will be a concrete structure, and 4,821 ft. embankment extensions.

A review of some of the construction details on the project will be found in the article, "Table Rock Dam," by Fred DeArmond, beginning on page 52.

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BPA

VOL. 34 NO. 2 MARCH-APRIL, 1956

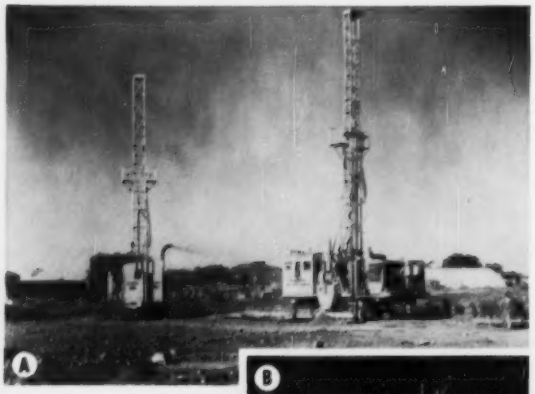
JOY DRILLS

on the St. Lawrence Seaway

Unquestionably one of the greatest construction jobs of the century, the St. Lawrence Seaway has drawn top-flight contractors, engineers, and construction men from across the country. When completed, this joint power venture will provide 2½ million horsepower, as well as a deep-draft sea channel to mid-America.

A job of this magnitude calls for various sizes and types of drills, and Joy builds them all. During initial phases of the Seaway project, scores of Joy drills are already at work—hand-held drills, wagon drills, and blast-hole drills (both hammer and rotary) for large diameter holes.

Joy offers the most comprehensive line on the market today. Whether you are digging a seaway or a sewer, there are Joy drills for the job. For details write **Joy Manufacturing Company, Oliver Building, Pittsburgh 22, Pa.** In Canada: *Joy Manufacturing Company (Canada) Limited, Galt, Ontario.*



A *Here are two of the three big Joy Champion air-blast rotaries now on the Seaway project. Joy Champions drill up to 12" diameter holes.*

B *Six Joy Challengers, world's biggest hammer drill (5¼"), are working for three Seaway contractors.*

C *At work on the Canadian side is this Joy Trac-Drill. It mounts twin extensible jibs (with power lift and power swing) and a Joy air compressor.*

Write for FREE Bulletin 58-5

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PLATO MALOZEMOFF

Plato Malozemoff

PRESIDENT

NEWMONT MINING CORPORATION

A Biography

PLATO MALOZEMOFF, president of Newmont Mining Corporation, is one of those rare individuals who combine exceptional ability and wide experience in the field of mining and metallurgy with unusual talents as an executive and administrator. His contributions to the mineral industry have won for him recognition as one of the top-flight leaders in the world of business today, both here and abroad.

Plato, as his friends and associates know him, was born in St. Petersburg, Russia, on August 26, 1909, the son of Alexander M. and Elizabeth A. Malozemoff. His father, a mining and metallurgical engineer, practiced his profession in Europe, South America, and the United States. In the 1920's, he was managing director of Lena Goldfields, Ltd., the largest American-English–financed mining concession in Russia. In the late 1930's, he was a consulting engineer in New York, retained, among others, by American Smelting and Refining Company. His mother, a graduate of the University of California at Berkeley with an M.S. degree in teaching, later was awarded a Ph.D. degree by the university.

Plato completed his elementary education at Lakeview Grammar and Oakland Technical School in Oakland, California, graduating with honors from both schools. He enrolled at the University of California and was graduated in 1931 with a B.S. degree in mining engineering, *cum laude*. He continued his studies at Montana School of Mines and, in 1932, was awarded an M.S. degree in mining engineering, *cum laude*.

When he was twenty, during the summer vacation from the university, he took his first job, working in the mine and mill of Morning Mine of Federal Mining and Smelting Company at Mullan, Idaho.

From 1931 to 1934, Plato was engaged in research for Montana School of Mines. During the following six years, he worked as a metallurgist with Alaska Juneau and Pan American Engineering Corporation. In 1940, he was employed as manager for private mining enterprises in Argentina and Costa Rica.

During World War II, Plato spent two years in Washington, D. C., in an engineering assignment with a United States Government war agency working on the premium price plan.

Mr. Malozemoff began his association with Newmont Mining Corporation in 1945, and, seven years later, was elected to a vice presidency in the organization. In May, 1953, he was made a member of the board of directors. In December of that year, he was honored by his fellow officers by being chosen Newmont's president.

Besides directing the extensive operations and varied interests of Newmont Mining Corporation, Plato Malozemoff's responsibilities include membership on the boards of directors of East Tennessee Natural Gas Company, Sherritt Gordon Mines Limited, Continental Oil Company, Cassiar Asbestos Corporation Ltd., O'Okiep Copper Company Ltd., Tsumeb Corporation Limited, Idarado Mining Company, and Southern Peru Copper Corporation.

Mr. Malozemoff is a member of the Mining Club, the Lawyers' Club, the University Club, the American Institute of Mining and Metallurgical Engineers, and the Mining and Metallurgical Society of America.

Plato Malozemoff married Alexandra Harlamoff on August 18, 1942, in San José, Costa Rica. They have two children, Alexis and Irene. The family home is in Greenwich, Connecticut.

Playing the violin is Plato Malozemoff's favorite hobby. He also finds relaxation from the demands of his business responsibilities in playing tennis, whenever time and opportunity permit such diversion.

Editorial

Lock Up Your Blasting Caps

For more than 30 years a nationwide campaign has been carried on by the explosives industry to warn children against the dangers of playing with blasting caps. We have enthusiastically supported this campaign with editorials appealing to users of explosives to make sure their supplies of caps are kept under lock and key when not being used.

In 1920, the Institute of Makers of Explosives initiated this campaign with a movie film entitled "How Jimmy Won the Game," which showed children some of the frightful injuries they could suffer if a cap were exploded near them. Subsequently, the movie warning was broadened to include the distribution of posters, leaflets, news releases, and radio scripts.

Later, a second movie film, called "Blasting Cap," was produced by the Institute to carry the warning to children. This second film, a two-reel, 16-mm. motion picture in color, has been shown to millions of children since its introduction.

About ten years ago, the member companies of the Institute distributed a blasting cap display board to show children what blasting caps looked like so that they would know a cap when they found one. These boards, with four actual-size dummy caps wired to the face of each board, have been a popular and effective means of showing children and their parents what to avoid.

Recently, the effort to carry the warning to children has been extended to that new medium of communication, television. Special films for the use of TV stations have been prepared by the Institute and are being shown by stations all over the country.

Enthusiastic Cooperation

The manufacturers of explosives, and the parents and guardians of our boys and girls, owe a special debt of gratitude to many organizations in this country that work with children. Enthusiastic and helpful cooperation has invariably been the answer whenever help was asked in carrying the warnings to the children of the nation. To name the groups that have helped is to name almost everyone who works or has ever worked with a child. The schools of the country and their teachers, the Boy Scouts and Girl Scouts, 4-H clubs, Future Farmers, summer camps, newspapers, radio stations, magazines, sheriffs, police and fire chiefs, the Bureau of Mines, the Post Office Department, insurance companies – all have helped gladly and efficiently in warning the children.

Obviously, when children have been warned to leave blasting caps alone, the other end of the chain of circumstances that leads to such accidents deserves attention – that is, how do these caps get into the hands of children? On this phase of the campaign, the Institute has had excellent cooperation from the users of explosives.

That the efforts on both of these fronts have been effective is proved by the steady decline in the number of children injured by blasting caps. In spite of a steady increase in the tonnage of industrial explosives used in this country and an equally impressive increase in the number of children who could be injured, the accidents have declined in numbers.

But the task of eliminating these tragic accidents is a never-ending one. New groups of children come along each year and the warning must be continued as long as there are blasting caps in places where boys and girls can find them.

An Urgent Appeal

In this continuing crusade against such accidents, the manufacturers of explosives are again making an urgent appeal to the users of blasting caps. Actually, the cooperation of the men who handle and use caps is just as important as the Institute's many warnings to children.

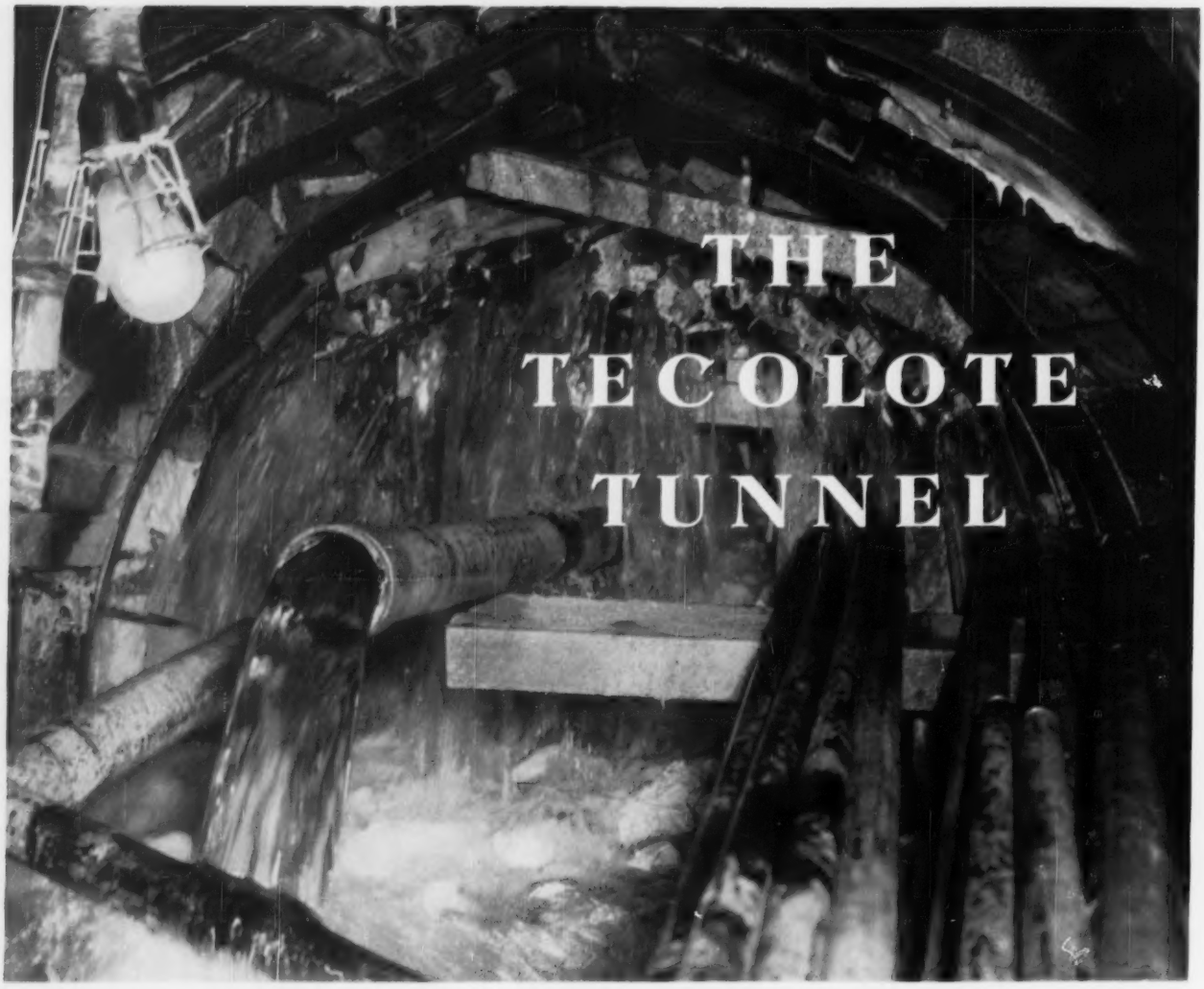
Reproduced on the opposite page is a newly designed poster provided by the Institute. Beginning this year, copies of the poster will be distributed to companies and individuals who handle and use dynamite and caps. It is a plea to everyone who works with blasting caps to keep them locked up when not in use.

The posters should be particularly impressive to anyone who works, or has ever worked, on a job where dynamite and blasting caps are used. The proper care of caps involves many things, and paramount among all considerations is safety in their handling and storage. Are your caps stored in such a way that children can never get at them? Are they kept safely removed at all times from the hands of mischievous, reckless, daring kids who want to have a little fun?

The posters will be distributed to all users of blasting caps by representatives of explosives manufacturing companies. If you have not as yet been given one of the posters, tear out the opposite page and tack it to the door of your cap magazine so your blasting crew and supply men can see it.

Blasting caps can cripple and blind! Lock 'em up so kids can't get at them.

BLASTING CAPS
can cripple and blind !
LOCK 'EM UP
so kids can't get at them



THE TECOLOTE TUNNEL

TYPICAL TECOLOTE HEADING: This photograph of the hazardous conditions at the heading in the outlet leg of Tecolote Tunnel, taken on December 2, 1951, is typical of what the contractor had to contend with. The water discharge through the tunnel heading was estimated at 2,500 gal. a minute. Steel rail spiling was driven forward over the top of the bulkhead. Drill rods for use with the core drill are piled at right.

A 6.4-mile-long tunnel "too hot, too wet, and too tough to handle" is holed through a ridge in the Santa Ynez Mountains to bring water to Santa Barbara and 30,000 acres of land in southern California

CHARLES F. THOMAS*

TECOLOTE TUNNEL, in the Santa Ynez Mountains about 9 miles northwest of Santa Barbara, California, is listed in construction records as one of the toughest, most difficult tunnels ever driven. For many months the formations in the headings were drilled, blasted, and excavated by the contractor's crews with no unusual happenings. Small flows of water were encountered and they were handled readily with pumps.

After an advance of 8,940 ft. had been made from the inlet portal into the mountain ridge in January, 1951, the tunnel was suddenly transformed into what the workmen termed "a snarling, vicious, fighting tiger." A rush of water and sand broke through holes in the round the miners were drilling and they were pushed from the heading. Before the flow was clogged, more than 200 ft. of the tunnel was practically filled with sand. During the inrush, workmen at the

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Los Angeles 1, California

heading accidentally set off an explosion of methane gas which had not been encountered previously. Eleven of the men were burned about their heads and faces. Fortunately, no permanent or fatal injuries were sustained. All work in the tunnel was stopped.

Tecolote Tunnel and Cachuma Dam and Reservoir on the Santa Ynez River comprise the key structures of the Cachuma project, one of the units in the U. S. Bureau of Reclamation's program in the West. Construction work on Cachuma Dam was completed in 1952. The structure, 3,000 ft. long and 206 ft. high, contains 6,500,000 cu. yd. of rock and compacted earthfill. It will impound 210,000 acre-ft. of water in a reservoir 5 miles long.

Tecolote Tunnel, with its inlet portal located midway along the west shore of the reservoir, is 6.4 miles long. With a diameter of 7 ft., it is designed to carry 100 cu. ft./sec. of water, with a velocity of 2.81 ft. a second. Between its inlet and outlet portals, the tunnel has a fall of only 8 ft., discharging its water into the head of the south coast conduit in Glen Annie Canyon at an elevation of 652 ft. above sea level. Its low gradient was maintained to increase the acre coverage in the districts below the conduit. Throughout most of its length, the tunnel is supported by standard horseshoe-shaped 4-in. H beams. Some 5- and 6-in. H beams were used in the heavier ground. The usual spacings between the supports were on 5-ft. centers.

Original estimates of the quantities involved in the construction of the tunnel were 78,860 cu. yd. of excavation, 2,853,000 lb. of steel for supports, and 20,480 cu. yd. of concrete for lining.

In December, 1949, bids were opened by the Bureau of Reclamation for the construction of the tunnel. A joint-venture bid of $4,750,455 by Carl Halvorson, Inc., Portland, Oregon, and H. Halvorson, Inc., Spokane, Washington, was the lowest submitted. A contract to do the work was awarded to the low bidder.

Work Began in May, 1950

Work was started at the outlet portal in May, 1950. The tunnel line was projected through alternating strata of siltstone, shale, claystone, sandstone, and conglomerate. Drilling was reasonably easy and the tunnel was advanced rapidly.

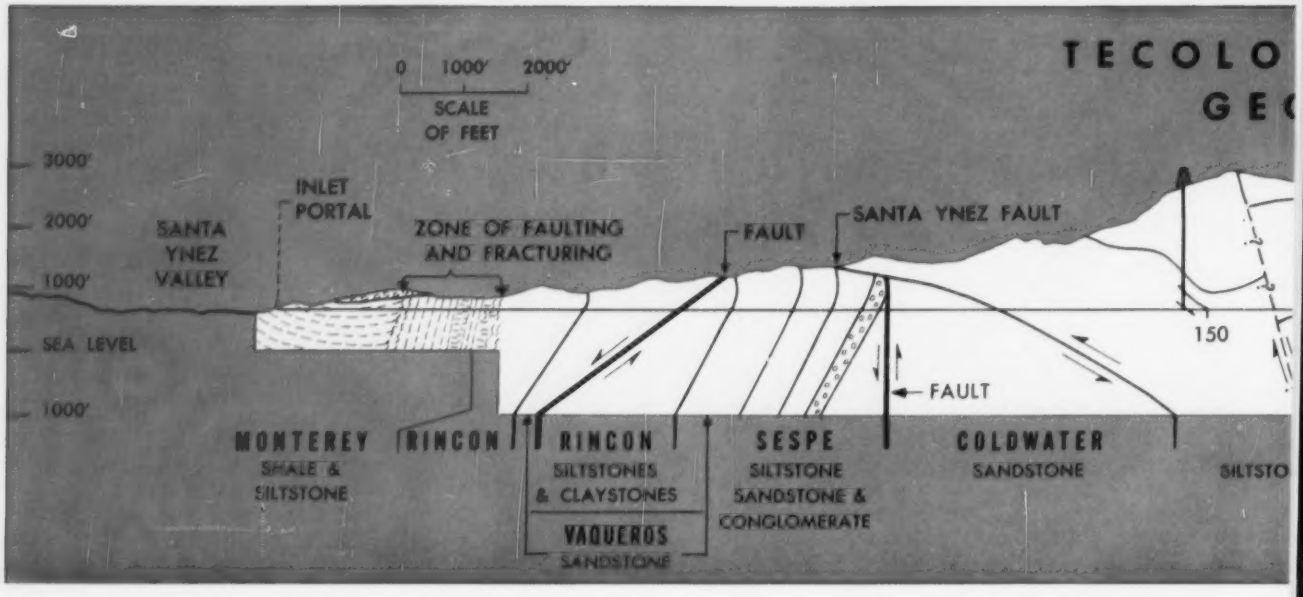
Preliminary geological studies indicated that the region was badly faulted. Of several that crossed the tunnel line, the major fault was the Santa Ynez fault, which is related to the great San Andreas fault that parallels the Pacific Coast from Oregon to southern California. The Santa Ynez fault represented a stratigraphic displacement of 12,000 ft.

As stated previously, the tunnel was advanced without undue difficulty until January, 1951, when work had to be stopped. At that time, tunnel progress from the inlet portal had reached a point 8,940 ft. into the mountain ridge.

Several months of work were required to construct heavy bulkheads and apply high-pressure grouting before tunnel driving could be resumed. Finally, after much careful work, the heading was driven through the trouble zone, a distance of 200 ft. In advancing through this zone, broken ground, water, and methane gas were encountered continuously. Grouting was evidently helpful in blocking free-running ground. After this zone was passed, good progress was made and the heading finally reached a point 14,919 ft. from the portal.

Because of the possibility of the inlet portal works being flooded from rising waters in Cachuma reservoir behind the dam, tunnel driving from the inlet portal was discontinued during the latter part of March, 1952, and lining commenced. The restricted tunnel diameter prevented the adoption of lining methods used in many other tunnel projects. Maintaining ventilation was a serious problem. It was solved by imbedding a 14-in. fan line in the concrete lining of the tunnel. This was

HEAVY GROUND PRESSURE: The pressure of heavy ground at a heading twisted and pushed the cut-off steel rib placed beyond the false set as tunnel support. The board spiling at the top of the picture was driven over the false set and into looser material beyond.



done by altering the original design of tunnel lining from the conventional horseshoe type to a circular section.

Concrete was batched from a plant at the portal and discharged into two-compartment cars after being lowered in a long batch bucket through a 24-in. shaft into the tunnel. Batched materials were emptied near placement locations through bottom-dump cars on a conveyor belt discharging into the mixer. After mixing, it was dumped to the wet belt and conveyed to the Pressweld concrete-placing gun. A 6-in. slickline extended from the gun to the forms where the concrete was placed in the tunnel section. Compaction was obtained by internal vibrators operated through the usual form windows and with form vibrators clamped to the form ribs.

Old-Time Method Adopted

Excavation from the outlet portal proceeded satisfactorily for several months. The ground was hard and no swelling was encountered. After an advance of 7,500 ft. from the portal, a flow of 1,200 gal. of water a minute poured into the tunnel. Progress was slowed but the heading advance continued until faulted and badly broken shale was encountered at 11,400 ft. Forced by a large increase of water under high pressure, rock and sand spread into the tunnel. The flow of water through the working face increased by about 3,500 gal. a minute.

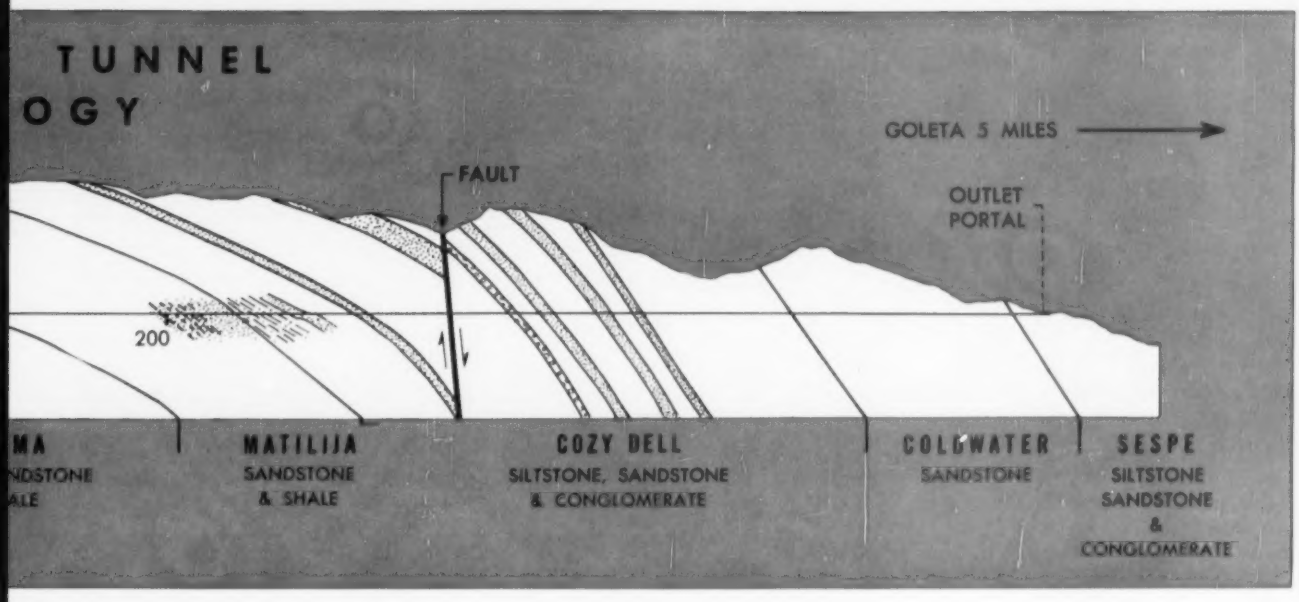
Two attempts were made to grout off the water behind two concrete bulkheads, but both failed. Grouting pressures up to 2,000 p.s.i. were used. Breastboards and heavy steel rail spiling were ineffective because of the small rock in the fauted zone. Finally, an old-time method, often used in wet, broken rock, was undertaken. Smaller drifts were driven on each side of the main tunnel in attempts to relieve water pressures. The face of the tunnel was slowly pushed inward as the side drifts were alternately driven ahead. This broken area was also about 200 ft. wide.

Because of the large increase of water within these last 200 ft., the tunnel was enlarged and immediately lined with concrete 24 in. thick. This lined section was extended for about 240 ft. An open-joint, perforated concrete pipe was laid in an invert trench and buried under the concrete lining. This drain pipe was connected with a steel pipe drain to a discharge pipe already in place. Water accumulating behind the concrete lining was forced by its own pressure to the portal. After many exasperating delays, work in the heading was resumed. Pilot holes 30 to 35 ft. long were drilled beyond the face and grouting was continued in the water-bearing seams. Records show that in driving the next 2,400 ft. of tunnel 104 grouting setups were made. More than 18,500 sacks of cement were used in attempts to seal off the water.

Adding to the difficulties already encountered from bad ground and heavy flows of water, temperatures increased from 87 degrees Fahrenheit where the lining was placed to 112 degrees at the tunnel face, about 14,000 ft. from the portal.

In July, 1953, the contractor had to stop work in the tunnel a second time. Since the start of work at the outlet portal, the elapsed time covered 40 long months of tough going that had severely tried the stamina and ingenuity of everyone associated with the project. To most men who work in tunnels, no rock is too hard, no ground too soft, no condition too severe for them to tackle. They adjust themselves to the situation at hand and jam, push, batter, and slug their way through any condition encountered. They strive each day to push ahead and make new tunnel-driving records.

Tecolote Tunnel had both the contractor and his men stopped. The estimates from yardages produced were very low and costs were extremely high. It was a job too hot, wet, and tough for older tunnel men to work in, and only a few younger men had the know-how to battle with it. In a total length of about 33,500 ft. of tunnel, approximately 29,000 ft. of advance had been made. Less than a mile of tunnel driving remained between the



two headings. The men could only guess what was ahead if they attempted to continue their work. As indicated, the job was shut down.

Subcontractor Takes Over

But, the Bureau of Reclamation had to hang on. All other units of the Cachuma project had been completed. Population in the districts was on the increase and more and more water was required to satisfy the needs of growing communities and of farms that had been reduced in size to provide additional homes for rural-minded city workers. The Bureau selected a board of engineers to study the Tecolote Tunnel problem and to recommend procedures that would permit completion of the job. The members of the board were Rush Sill, a consulting engineer of Los Angeles; Walker Young (retired), former chief engineer of the U. S. Bureau of Reclamation at Denver; and Frank Purvis of Denver.

After thorough examinations and discussions, the board recommended that the tunnel be completed at any cost because of the seriousness of the situation. The prime contractor suggested that a subcontract be awarded to an organization with wide experience in tunnel construction. Finally, arrangements were made with two firms, Coker Construction Company and Peter Kiewit Sons' Company, to finish the job on a joint-venture subcontract basis. The subcontractors agreed to complete all unfinished work items in connection with the tunnel. They accepted all prices bid by the prime contractor in the original bid with the exception of the price for tunnel excavation. The price bid by the Halverson firms was $44 a cu. yd. The newly negotiated price totaled $447 a cu. yd. This figure seemed to be fantastically high. But, it covered every contingency that might arise during completion of the tunnel. The new price included grouting, installation of pipe, etc., if the subcontractors elected to use such methods. Also, it applied only to the less than 12,000 cu. yd. of material remaining to be excavated in the uncompleted section of 4,716 ft. of tunnel.

The merits of the amended contract have been demonstrated. What appeared to be an almost impossible task was completed and the Tecolote Tunnel was holed through successfully.

Tunnel Advance Proceeds Under Almost Unbearable Conditions

Coker-Kiewit crews moved onto the job in January, 1954. The temperature in the tunnel continued to rise until an atmospheric high of 110 degrees Fahrenheit was reached. The relative humidity varied from 80 to 100 per cent. The flow of water from underground fissures increased until more than 9,000 gal. a minute were being handled throughout the length of the tunnel. Sulfureted hydrogen escaped from seams to help foul the air and burn the eyes. The temperature of the water climbed to 117 degrees.

Complete rehabilitation of the tunnel and all facilities was started. Supports were reblocked or lagged. All dewatering units were changed or improved. After-coolers were installed on four big Joy compressors that supplied air to the drills and other equipment and furnished cooled dry air at the headings. Tunnel crews were reorganized. Once more, the tunnel began to grind slowly ahead.

Actually, advancement of the tunnel heading began on April 12, 1954, and during the first four weeks 375 ft. were driven. This advance was stepped up until an average of 115 ft. a week was attained. And on January 15, 1955, the outlet portal heading was holed through to the inlet portal heading. It was an occasion for relief and rejoicing. Along with much publicity, the event was celebrated with a big holing-through party at the Mar Monte Hotel in Santa Barbara.

The Underground Bathtubs

One of the most unusual and much publicized features of the job under the direction of the Coker-Kiewit organization was the transportation of workmen to the tunnel heading in

"bathtubs" – mine cars filled with cool water. The men rode to their working places in these water-filled cars, and, during rest periods, went back to the sidings where the cars were spotted to dunk themselves. The fact that they were clothed did not matter because they were constantly saturated with the tunnel water or soaked with perspiration within minutes after entering the tunnel. These immersions helped to combat the enervating action of the extreme heat and humidity.

One of the first moves in the Coker-Kiewit program of operations was to improve facilities for handling the water problem. A pump station 17 ft. wide and 65 ft. long was located at a point 2 miles within the tunnel. Also, a sump was dug 8 ft. deep. Two 3,000-gal. Fairbanks-Morse pumps driven by electric motors were installed. In addition, there were two 6-in. 50-hp. Gardner-Denver units pumping 1,200 gal. a minute, and one 10-in. Ingersoll-Rand 250-hp. centrifugal unit pumping up to 3,150 gal. a minute. These pumps, with starting boxes, switches, and various fittings, were crowded into the narrow pump station. At one time, 20 or more pumps were operated along the tunnel. All water pumped was discharged through one 14-in. line and two 12-in. lines. During lining work, a vacuum pumping system proved highly efficient.

Protecting haulage locomotives and other electrical equipment was an almost impossible task. Water was so deep in many places that motors were submerged. Occasionally, it reached the seats on the man cars. The intense humidity short-circuited telephones, pump motors, and switch boxes.

When Coker-Kiewit crews started operations, the tunnel face had been advanced about 3 miles. Ventilating friction surfaces were great and efficiency was low. A 200-hp. Sutorbilt blower delivering 5,000 ft. of air at 10 p.s.i. was installed. A mile from the face a 125-hp. Sutorbilt booster was also added to aid in pushing air to the heading through a 14-in. line. Air-driven pumps were installed in several locations. This large quantity of air also helped to reduce the hazards of explosive gas accumulations.

Drilling and Blasting

Except for faulted and broken ground through which the tunnel was driven, the rock formations presented no real difficulties. They were readily drilled and blasted, and easily supported. Both contracting groups used Ingersoll-Rand DA35 and DB35 drills. Three machines mounted on an I-R Hydra-Boom took the place of the jumbo usually found in the larger tunnel headings. Through most of the tunnel's length, Timken carbide insert detachable bits were used on 1¼-in. steel. In the softer ground, throw-away bits were used.

The usual round in a heading consisted of 25 to 32 holes drilled 6 ft. deep. Because of the variable nature of the ground, there was no typical plan of cut holes. The drill holes were loaded with 40 to 130 lb. of gelatin dynamite 40% strength in standard-size cartridges. The charges were primed with No. 8 delay electric blast-

DIVERTING WATER FLOW: This picture shows a part of a drainage drift which was driven out from the main tunnel in an attempt to intercept and divert the flow of water from the tunnel's main heading.

TIME OUT FOR LUNCH: At lunch time, the contractor's heading crew went back to a specially prepared place where a spring of water, temperature 80 degrees, flowed into the tunnel. One of the men at rear is about to have a drink from the spring.

ing caps, from 1 to 8 periods of delay. The leg wires of the caps were connected in parallel to a buss wire strung on wooden pegs driven into specially drilled holes. The charges were detonated by a firing circuit supplied with 220-volt A.C. current.

As the flow of water increased, the difficulties in loading explosives charges into drill holes in the heading increased. In wet rounds, additional holes were drilled to permit abandoning one or more if the water flow delayed or otherwise interfered with loading operations. In some cases, hot water flowing from drill holes softened and dissolved some of the explosives cartridges. All charges were stemmed with heavy waxed paper containers filled with sandy clay from outside the tunnel.

The quantities of explosives used in each round, the rotation of firing, and the detonation of the charges were under the direct supervision of the shifters.

The results from blasting averaged 2½ cu. yd. of broken rock per linear foot of tunnel advance. Overbreak was surprisingly low. Mucking was done with Eimco 21 air-operated loaders that dumped into 1⅛-cu. yd. steel side-dump cradle cars. Cars loaded with muck from the blasts were hauled to the dump area outside.

All explosives supplies were kept in magazines outside the tunnel. When needed in the underground workings, they were transported into the tunnel in insulated, double-compartment cars lined with heavy rubber mucker belt. Access doors opened on the tunnel side opposite the high-voltage power lines.

Special Equipment

All transportation and haulage was done with 7-ton Atlas battery locomotives especially designed for this tunnel. The locomotives were long and only 32 in. wide. Motive power was derived from 48-cell Exide batteries. The front and rear ends of the locomotives were narrowed to permit radial clearances as they turned or passed on the narrow California switches used in the tunnel. Track gauge was only 24 in.

All equipment used in the Tecolote Tunnel reflected the small diameter of the bore. Everything was squeezed into a shape that would pass through the narrow spread of 7 ft. 9 in. between the legs of the steel tunnel supports. The man cars were long and low-seated — workmen held their hard-hatted heads down as they rode under the many installations that crossed the tunnel's arch.

Outside installations included four 10 by 7 Joy compressors, each producing 1,650 c.f.m. of air at 125-lb. maximum pressure. The after-coolers installed by Coker-Kiewit between the compressors and the receiver tank proved invaluable to the current operation. A machine shop, an electric shop, and a battery-charging station were highly necessary adjuncts to the work. Glen Annie Canyon, like the small-diameter tunnel, is restricted in width. As a result, shops, warehouses, changerooms, and offices had to be crowded within its sloping sides and located at points most convenient for job efficiency. The batch plant for tun-

THE BATHTUBS: One of the most unusual features of the job under the direction of the Coker-Kiewit organization was the transportation of workmen to the tunnel heading in bathtubs — mine cars filled with cool water from a spring. When this picture was taken, the temperature in the tunnel was 97 degrees.

nel concreting together with aggregate stockpiles, bins, elevators, and switching tracks lie less than 300 ft. from the tunnel portal.

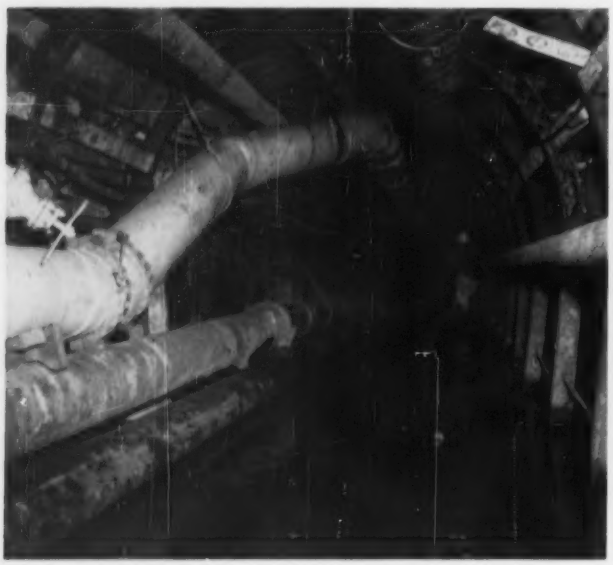
Safety of all employes on the job was an important feature of this project. Everything possible was done to prevent accidents. Everyone working underground was equipped with an Edison model P electric cap light. Constant observations were maintained to prevent accumulations of poisonous or explosive gases. An M-S-A Explosimeter was used regularly to test the air in the tunnel. Wet and dry bulb thermometer readings were taken at various underground locations.

All cars and motors were equipped with Willis automatic safety couplers. At the outlet portal a brilliant red light signal and a siren warned of the approach of locomotives from the tunnel. A new, modern wash house and changeroom was built by Coker-Kiewit near the outlet portal. Strict physical examinations were given to all prospective employes.

Remarkable Engineering Accomplishment

Engineering skill of a high order prevented many unusual situations from becoming serious problems. Some of these were encountered in the preliminary location work. Practically all surveying was done at night — the heat and sunlight during the day caused much refraction. Because of the rolling hills and dense brush, high towers were built on the tops of ridges along the tunnel line. The necessary readings were made from these towers before the locations and elevations could be determined accurately. When the engineers moved underground, their real troubles began. Delicate instruments soon got out of adjustment. Lenses fogged or were splashed with water. In many cases, distances of 15 or 20 ft. could not be measured precisely. That the two tunnel headings finally met with only inches of offset in line and grade is amazing.

Besides presenting a tunnel-driving outfit with a job that combined every imaginable difficulty underground, Mother Nature added outside troubles. In September, 1955, a serious brush fire occurred in the canyon and hills



THE DISCHARGE PIPES: Here is a look at the 14-in. discharge pipes going into the arch of the tunnel to get over a passing track. There was not enough room in a passing track area for the pipes to be placed at the side of the tunnel.

A CALIFORNIA SWITCH: The front and rear ends of the contractor's locomotives were narrowed to permit radial clearances as they turned or passed on the narrow California switches used in the tunnel. The gauge of the track used was only 24 in.

AGITATOR CARS: For placing the invert, trains of three agitator cars, each 3½-cu. yd. capacity, were used. To empty the cars, end doors and drawbar pins were removed and the cars telescoped together to become one long, cylindrical container.

adjacent to the tunnel portal. In California, brush fires are fearful things and for two days the portal installations were seriously threatened. Several fire-fighting units were employed to combat the flames. Water flowing from the tunnel helped in preventing damage. Late in the second day, a change in wind direction shifted the flames but not until they had burned to within 50 ft. of the portal and buildings of the camp.

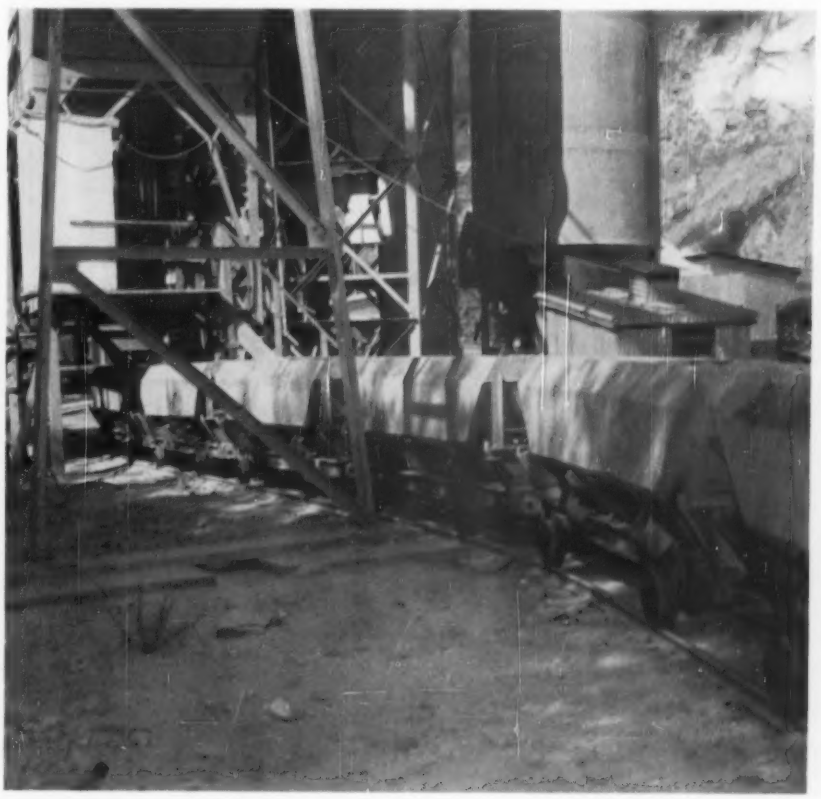
Since the tunnel was holed through, the subcontractor made some radical changes in concrete-lining procedures. The full tunnel is lined in a monolithic placement with specially designed circular steel forms and with concrete placed with a Rex Pumpcrete model 200.

After all construction details are completed and the Tecolote Tunnel is ready for use, water will be distributed through the south coast conduit of the project to 30,000 acres of land in Goleta, Montecito, Summerland, and Carpinteria water districts, and to Santa Barbara and vicinity.

Personnel

For the Coker-Kiewit organization, the project manager is A. M. Coker, president of Coker Construction Company. Ray Blasongame was general superintendent for the subcontractor during part of the tunnel-driving activities. His successor, Charles Conrad, completed the driving details. D. R. McGregor is the chief engineer; W. W. Roberts, the superintendent of the concreting operations; and J. S. McMullin, the office manager.

For the U. S. Bureau of Reclamation on the Cachuma project, E. R. Crocker is project manager. The contracting officer is L. N. McClellan, assistant commissioner and chief engineer of the Bureau, with offices in Denver.



TWO-COMPARTMENT CARS: Concrete for lining the tunnel was batched from a plant at the portal and discharged into a train of two-compartment cars. Each compartment was loaded with ¾-cu. yd. of weighed aggregate and cement.

A DIFFICULT HIGHWAY JOB IN PENNSYLVANIA

Approximately 2,230,000 cu. yd. of rock in heavy sidehill cuts were blasted without damage to abutting properties or interruption of traffic along a parallel roadway

W. C. BURKLE*

THE Commonwealth of Pennsylvania, Department of Highways, received bids on October 22, 1954, for the construction of a modernly designed four-lane highway at the town of South Heights, near Aliquippa in the western part of the state. The work involved unusually difficult grading and draining problems. Also, deep cuts had to be made through a sidehill approximately 2½ miles long that lies parallel to Constitution Boulevard, a thoroughfare connecting the towns of South Heights and Aliquippa.

Travel along the boulevard has been hazardous for some time. The sides of the hill sloped directly onto the roadway and rock and earth slides were an ever-present danger. In some places, steep cliffs of deteriorating sandstone and shale overhung the boulevard. These hazardous conditions were particularly acute during spring and summer months when

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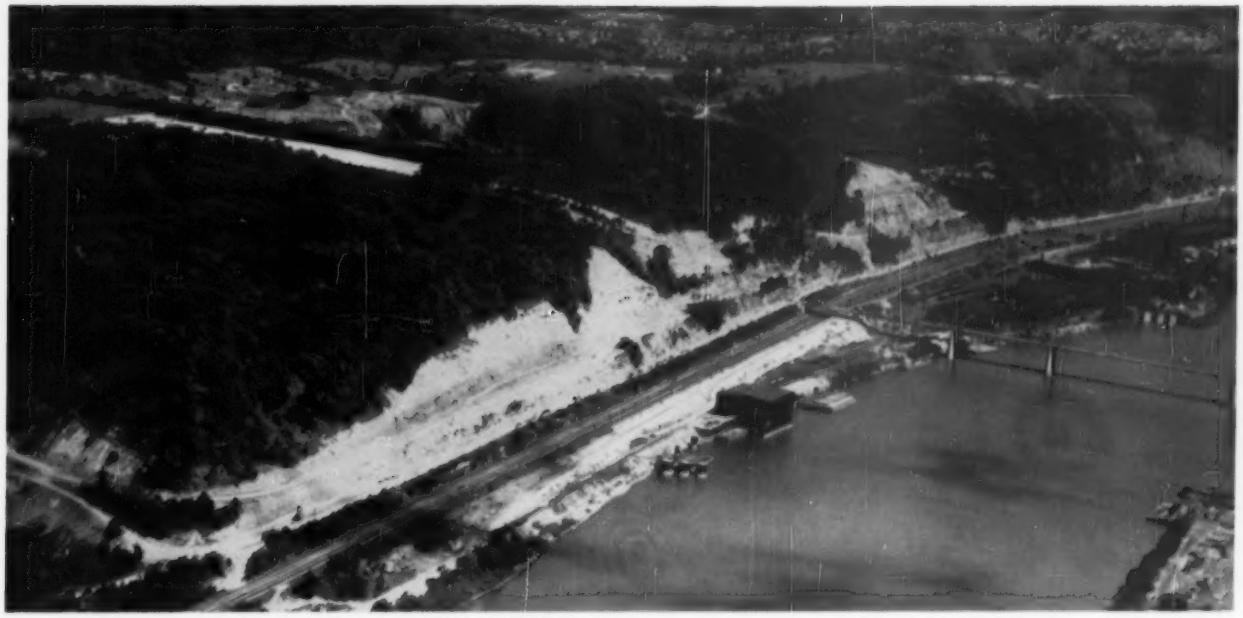
603 Stanwix Street
Pittsburgh 22, Pennsylvania

DIFFICULT OPERATING CONDITIONS: This view of the South Heights project from an airplane reveals some of the difficult operating conditions the contractor had to contend with. Deep cuts had to be drilled, blasted, and excavated through rock in a hillside. The resulting muck had to be hauled up and down steep grades. While these activities were in progress, two-way traffic had to be maintained at all times on the boulevard below and alongside the job, and no damage done to railroad main-line tracks and a steel plant that parallel the boulevard.



PANORAMIC VIEW: The photographer referred to this picture as a long view of the job, encompassing about three-quarters of its length. Also included in the picture are the Ohio River in foreground, followed by the Aliquippa Works of the Jones and Laughlin Steel Company, at right, then the Pittsburgh and Lake Erie Railroad tracks, and Constitution Boulevard.

greater precipitation provided lubrication sufficient to produce mass movement of the material on the sides of the hill.

After the bids had been opened and read by the Commonwealth officials, the lowest total submitted was $3,669,071.91 by Nello L. Teer Company of Durham, North Carolina. The contract to do the job was awarded to the low bidder. Teer company forces and equipment were moved in, and work on the four-lane highway project was started in January, 1955.

2,230,000 cu. yd. of Rock

In the contract specifications, Class 1 excavation called for 2,787,179 cu. yd. of material to be removed, of which 2,230,000 cu. yd. were estimated to be rock. About 80 per cent of this rock estimate was a hard, dense shale, and 20 per cent was primarily sandstone interbedded with shale. The six major cuts to be made through the sidehill had depths of 320, 280, 245, 225, 210, and 195 ft., respectively.

Besides the rough, rocky terrain along the job location, several other obstacles presented problems that required operating know-how of a high order. The project is bounded along its entire length by Constitution Boulevard and the main-line tracks of the Pittsburgh and Lake Erie Railroad Company. Within the shadows of the hill lie the extensive Aliquippa Works of Jones and Laughlin Steel Company. The industrial towns of South Heights and Aliquippa bordering the Ohio River are at the northern and southern ends, respectively, of the job site. Across the river and to the northeast is the town of Ambridge. And last, but not least, two-lane traffic had to be maintained 24 hours a day while construction work was in progress.

Drilling and Blasting

The rock formation that had to be drilled and blasted with explosives presented a wide range of hardness. At times, Mayhew drills, Model 1000, averaged 2.5 ft. of 4¾-in.-diameter hole a minute. In some places, drilling speed was reduced to 1.5 ft. of hole a minute.

Most of the drilling of blast holes was done with five of the Mayhew units; three were mounted on Caterpillar tractors and two were operated from diesel trucks. All of these drills were equipped with RotoClone, Type D, dust collectors. In the areas where smaller diameter and closer spacings of holes were desired, a Gardner-Denver drill mounted on an Air-Trac carrier was used. Two Gardner-Denver wagon drills were also employed. The drill steel was of Timken manufacture, in lengths of 6 to 20 ft. The detachable bits were also made by Timken in 2 to 2¾-in. diameters. Air for the drills was supplied by three compressors: an Ingersoll-Rand 600 c.f.m., a Gardner-Denver 600 c.f.m., and a Jaeger 105 c.f.m.

Typical Primary Blast

A typical primary blast included 90 to 100 holes drilled 4¾ in. in diameter, 15 to 20 ft. deep, spaced on 8 by 8-ft. and 10 by 10-ft. centers. The depth of the holes drilled on the side adjacent to the hill was varied whenever one of the several slide benches was involved in an area to be blasted.

The larger diameter blast holes were loaded with 4½-in. by 12½-lb. cartridges of extra dynamite 40% strength. Holes drilled with Air-Trac—mounted units and wagon drills were loaded with 1½ by 16-in. cartridges of a semigelatin grade of dynamite. In a rotary hole, the maximum charge was 50 lb. of explosives. In many instances, holes that bordered the outside edge were loaded with a 25-lb. charge. Considerable deck-loading was done, with a 37½-lb. charge in the bottom of a hole and a 12½-lb. deck charge located 8 ft. from

UNINTERRUPTED TRAFFIC: This view shows a Marion model 111 shovel with a 4-cu. yd. dipper excavating blasted rock in one of the cuts with two-way automobile traffic moving on the boulevard below without interruption.

the collar of the hole. The explosives loading factor varied according to conditions encountered, ranging from 0.60 to 0.75 lb. per cu. yd. of material in the solid. The charges were primed with short-period delay electric blasting caps, 1 to 10 periods of delay, with leg wire lengths from 12 to 30 ft. Drill cuttings were used to stem the charges to the collar of each hole. The cap wires were grouped in balanced series which were connected in parallel. Blasts were fired with a condenser-discharge type of blasting machine.

In maintaining uninterrupted two-lane traffic at all times, it was extremely important to control the movement of rock broken by blasting. Its movement had to be directed away from the roadway, and, at the same time, good fragmentation had to be obtained to expedite job progress. Both of these conditions were realized by the employment of the right grades and sizes of dynamite and the pattern in which short-period delay electric blasting caps were used.

Excavation

In handling the excavation details, the Teer company used four diesel-powered shovels: two 4-cu. yd. 111 Marions and two 2½-cu. yd. 80D Northwests. Each shovel loaded into a fleet of from five to seven Euclid trucks, each 22-ton capacity. A workman was stationed at each shovel. He was responsible for directing the trucks into loading position without unnecessary jockeying back and forth. This man also maintained a record of the number of trucks loaded. The records provided the foreman with a constant check of the yardage moved each day. In hauling the waste rock for disposal, the Euclids had to negotiate grades that averaged 15 per cent. At one location, a 23 per cent grade was encountered. Four large hollows at the rear and above the project were used as waste-disposal sites.

A particularly difficult task confronted a shovel operator when working at one of several slide, or safety, benches on the project. Usually the bench grade was carried through its entirety, following which the remaining portion of the cut was excavated. The benches nearest the road level were 20 ft. wide, while others measured 14 ft. The front-to-back slope was 1½ in. to 1 ft. The benches formed a zigzag pattern up the face of the cuts. They were designed to halt and catch slides and to provide accessibility to clean-up crews. The two highest cuts were traversed by six benches, while the other cuts were protected with two to four of these features.

Excavation details accounted for the removal of an average of 7,000 cu. yd. of material a day. Accompanying photographs indicate some details of excavation and transportation on the job.

It may be of interest to record that cross sections of the project were plotted from a contour map having a scale developed by photogrammetric methods. When the construction contract is completed, the same means will be used to determine the total cubic yards excavated. As work on the job progressed, W. E. Hankins, Jr., project engineer for the Teer company, and his party calculated and maintained a record of the material removed.

Equipment and Personnel

Of prime importance on any heavy-construction job is the level of mechanical efficiency at which the equipment is maintained. At this western Pennsylvania location, the Teer company assembled many kinds and types of valuable construction equipment. Equally important, the equipment was

DRILLING BLAST HOLES: Most of the drilling of blast holes was done with Mayhew drills, Model 1000. Three were mounted on Caterpillar tractors and two on diesel trucks. All of the drills were equipped with Roto-Clone, Type D, dust collectors.

kept that way. Included among the principal operating units were: two Marion 111 shovels; two Northwest 80D shovels; twenty 22-ton Euclid trucks; two Caterpillar No. 11 motor graders; three D8 Caterpillar tractors; three D6 Caterpillar tractors; one D6 Caterpillar high lift; one Allis-Chalmers HD-9 high lift; five Mayhew rotary drills, Model 1000; one Air-Trac drill carrier, Model 60WD; two Gardner-Denver wagon drills; five pick-up trucks and one passenger car, all two-way radio equipped; one master radio station; and two Motorola walkie-talkie radios for the road patrol.

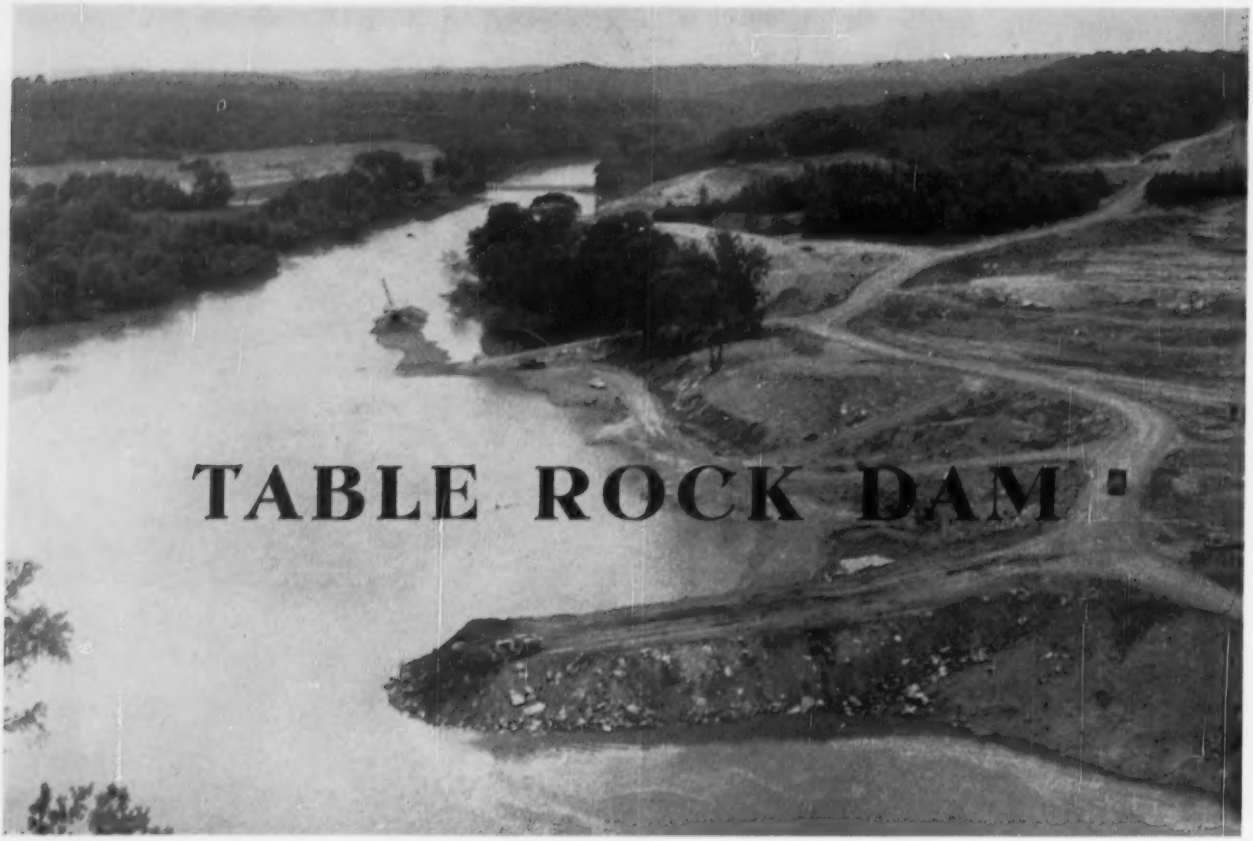
The Commonwealth of Pennsylvania was represented on the project by William White, resident engineer, and D. B. Boyers, assistant construction engineer.

The administrative officers of Nello L. Teer Company are Nello L. Teer, Sr., chairman of the board of directors; Nello L. Teer, Jr., president; Dillard Teer, vice president and treasurer; and James Love, vice president in charge of construction. On the highway job at South Heights in western Pennsylvania, Robert Tidwell was project manager until early in February of this year when he was succeeded by William Burton. Others in a supervisory capacity were William E. Hankins, Jr., project engineer; Charles C. Waller, John R. Carrickhoff, and Neuma H. Moser, grade foremen; Roy Young, drill superintendent; George J. Walker, mechanical foreman; Guy E. Keith, labor foreman; Herman F. Connor and Harry T. Emery, safety men; and Samuel O. Beasley, office manager.

LOADING OUT MUCK: One of the Teer company's 4-cu. yd. Marion diesel shovels loading blasted material into a Euclid truck. Waste material was deposited in four large hollows above and at the rear of the project.

WATCHING JOB PROGRESS: Inspecting operations on the South Heights job from one of the higher benches are, left to right, Nello L. Teer, Jr., president of Nello L. Teer Company; Robert E. Tidwell, the company's project manager during the early stages of the job; and James Love, vice president in charge of construction for the Teer company.

TABLE ROCK DAM



SOON AFTER WORK BEGAN: This upstream view of the White River shows the partially completed coffer dam as it looked seven months after work began on the construction of Table Rock Dam. In the center, a dredge is at work and an access bridge is just beyond. Earth-fill requirements were obtained from the borrow area at upper left.

Completion of a $78,000,000 high-dam structure on the White River in July, 1958, will control flood waters and provide facilities for more and cheaper power in the Ozark country

FRED DE ARMOND*

FOR many years, water management in the Missouri - Arkansas - Oklahoma Ozarks has been a matter of real concern. At some seasons, there is a parching dearth of water in this Ozark country; at other times, the water rushes down to the sea, destroying crops and carrying away a huge tonnage of much needed soil. Two schools of thought contest for the solution to this problem. One contends that the water should be held on the land where it falls, with the runoff retarded by terraces, ponds, reforestation, and small dams near the headwaters of streams. The other says that this treatment is not enough to prevent floods in the lower valleys, and that the water must be impounded in great lakes by high dams. Insofar as the White River is concerned, the second alternative has prevailed. It was adopted because the high-dam theory provided control of flood waters and facilities for the generation of more and cheaper power for the growing demand in the Ozarks.

Table Rock Dam is a multipurpose dam under construction at a location 6 miles west of Branson, Missouri, and 10 miles from the Arkansas line. Upon completion, it will combine facilities for flood control, hydroelectric power generation, and recreation. It represents the third in a series of five high dams by which the Army Corps of Engineers expects to manage the waters of the White River. Two other similar dams, Norfork and Bull Shoals, both in Arkansas, are already in existence. A privately owned hydroelectric project, the Taneycomo Dam in Missouri, is located between Bull Shoals and Table

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Springfield, Missouri

Rock. Fourth and fifth in the series are to be constructed on the Arkansas side, one upstream from Table Rock and one below Bull Shoals.

Rising in northwest Arkansas, the White River flows through three counties in southern Missouri, then back into Arkansas to pour its waters finally into the Mississippi River, some 700 miles from the source.

In 1912, a private utility company chose the spectacular Table Rock bluff in Missouri as a likely site for a power dam, and obtained a license for its construction. When this license expired in 1935 without action, the Army Engineers interested themselves and finally selected a similar site 1½ miles upstream because, in their opinion, it provided a better foundation for a dam.

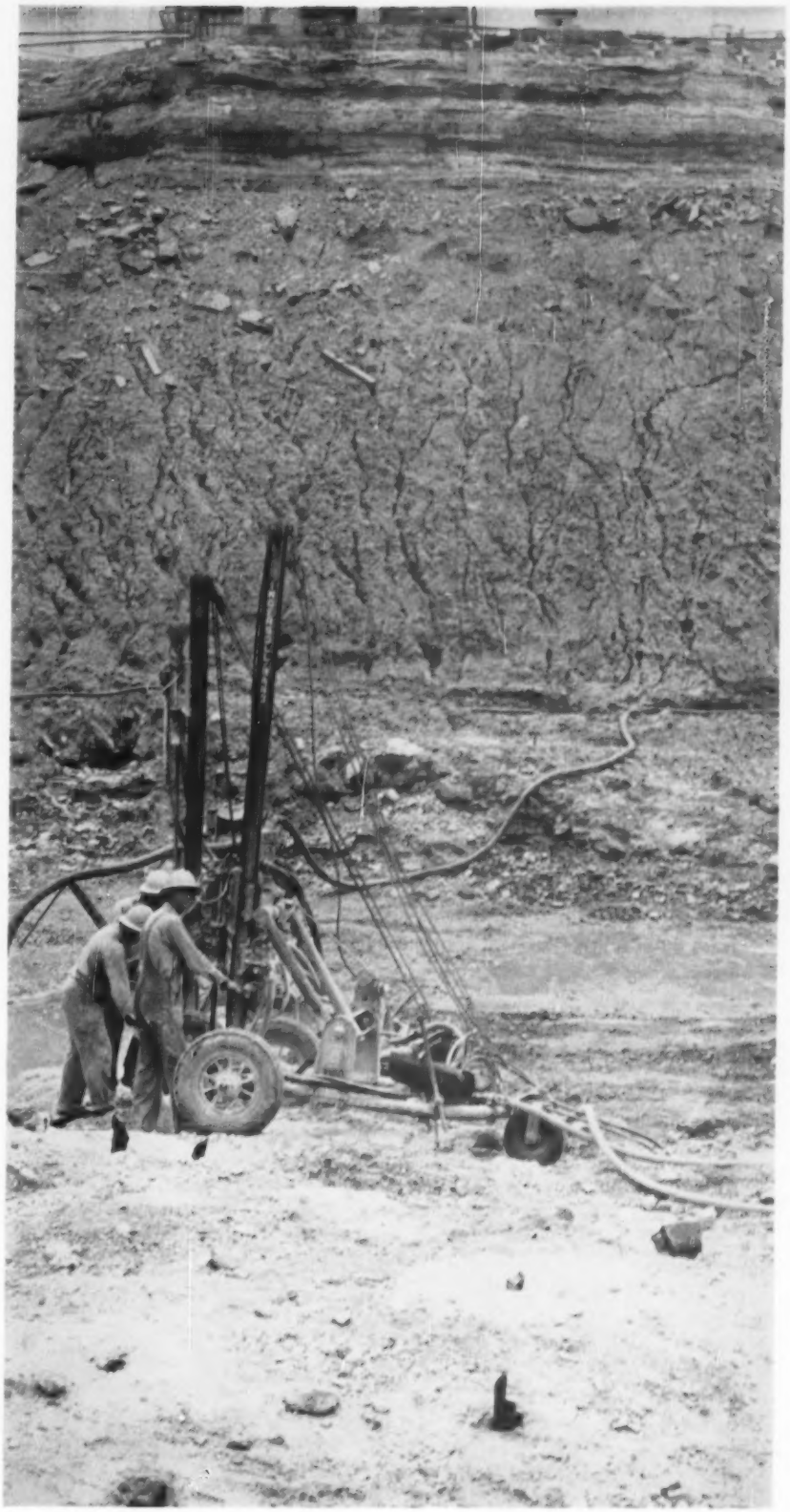
Congressional approval for a multipurpose dam to cost an estimated $78,000,000 was obtained just before World War II. But, owing to the opposition of Missouri conservationists and other factors within the state, no substantial appropriation was forthcoming until 1954. At that time, a construction contract amounting to $24,000,000 of the total cost was awarded to a combination of two large firms, Morrison-Knudsen Company, Inc., of Boise, Idaho, and Utah Construction Company of San Francisco, California.

Contract Specifications

Above the dam, it is proposed to impound 770,000 acre-feet of dead power water storage, 1,932,000 acre-feet of power drawdown storage, and 760,000 acre-feet of flood-control storage. The reservoir will extend upstream for about 70 miles and embrace a shoreline of approximately 800 miles. The upstream watershed drainage area is computed at 4,020 square miles.

To accomplish the impoundment, the project specifications call for a dam with an overall length at the top of 6,423 ft., of which 1,602 ft. will be a concrete structure, and 4,821 ft. embankment extensions. Maximum height above the lowest foundation will be 261 ft., and the embankment 175 ft. At the base, the width is 220 to 250 ft.

Two 50,000-kw. power-generating units will be installed at completion of the construction work, and two more



STILLING BASIN AREA: For blasting rock formations in the stilling basin area, the contractor's crews drilled holes 2¼ in. in diameter, 21 ft. deep, spaced on 6 to 8-ft. centers. Blasts were fired with charges of 40 per cent dynamite primed with short-period delay electric blasting caps, zero to 7th periods of delay.

later. They will provide an output, in terms of annual primary energy, of 346,000,000 kw.-hrs. In addition, by permitting better regulation of the White River, Table Rock Dam will increase the average energy output of the Ozark Beach plant at Taneycomo by 35,000,000 kw.-hrs. a year. The output at Bull Shoals Dam will be increased by 40,000,000 kw.-hrs. annually.

Construction Details

At the damsite, White River has cut a channel to a depth of 700 ft. below what was originally a plateau. The channel is on a slight curve in the river, just downstream from a large bend. A high bluff, elevation 940 ft., is on the right, and a gently sloping flood plain 600 ft. wide is on the left.

A yellowish-buff and red clay containing chert fragments from minute sizes to small boulders comprises the material on the surface. The rock outcrop is limestone of Mississippian age, rather friable and with a high chert content. Underneath the outcrop is a harder and more compact Ordovician limestone on which all the foundations of the structure rest.

For the dam abutment, the steep right bluff was cut down in some 50 narrow steps by means of line drilling at 4-in. intervals. The slope was one-quarter to one. On the left bank side, the foundation is in a series of 12 terraces, each 54 ft. wide.

At the top of the right bank bluff, a Johnson mixing plant with three 4-cu. yd. mixers and a peak capacity of 175 cu. yd. of concrete an hour is located. There are two quarries—one for riprap just above the flood plain on the left bank, and the other for the production of crushed stone for aggregate purposes. The latter quarry is located on Baird Mountain, 1⅛ miles south of the mixing plant, a site provided for the contractor by the Army Engineers. With an elevation of 1,340 ft., this hill is the highest in Taney County, the most mountainous region in the 115 counties in Missouri. It rises 400 ft. higher than the bluffs at the damsite. Opening the quarry was an extremely difficult job, beginning with the building of a road that had to spiral up the mountainside. A 40-degree slope of the hill necessitated blasting benches into the formation to provide floors for equipment and to establish the various working faces.

The construction of Table Rock Dam will require approximately 700,000 cu. yd. of rock fill, 2,600,000 cu. yd. of dirt fill, and 1,300,000 cu. yd. of concrete. Altogether, some 1,600,000 cu. yd. of aggregate will go into the project.

Dirt for the big fill at the north approach to the dam is obtained largely from a bottom field upstream and on the right bank. A temporary access bridge was built for this purpose. Another bridge downstream from the dam is for transportation between the quarry and the mixing plant installations on the south side, and the main project center on the north. In building bridges, ample allowance had to be made for a safety margin so that the bridges would withstand floods that are sure to come during the 3½ years it will take to complete construction of the dam.

Baird Mountain, source of the aggregate material, is a long ridge that roughly parallels the river at this point. At its western foot, a Superior-McCulley gyratory crusher was erected. Here the blasted rock is crushed and then moved by belt conveyor to a primary surge pile. To eliminate a rough

MUD POCKETS: In some of the quarry areas, seams of clay 50 ft. deep and from 5 to 20 ft. wide were encountered all the way down the working faces. When this condition existed, it necessitated blasting up to a seam, removing the clay with a power shovel, and then resuming normal drilling and blasting procedures.

PRIMARY CRUSHER: Trucks loaded with blasted rock from the Baird Mountain quarry end-dump their contents onto a chute that discharges directly into the primary crusher. After the crushing operation, the crushed rock is transported by a conveyor belt at the bottom of the plant to the primary surge pile.

SECONDARY SURGE PILE: From the primary surge pile at the quarry to the secondary pile near the mixing plant more than one mile distant, the crushed stone is moved on a conveyor belt. While en route, it is passed through a scrubbing station.

haul of something like half a mile, a chute was carved into the side of the hill so that broken rock from the quarry could be dumped down the chute directly into the crusher. The mountain is being quarried down to the top of the crusher chute and down the ridge as far as is necessary to obtain the rock required on the project.

Drilling and Blasting

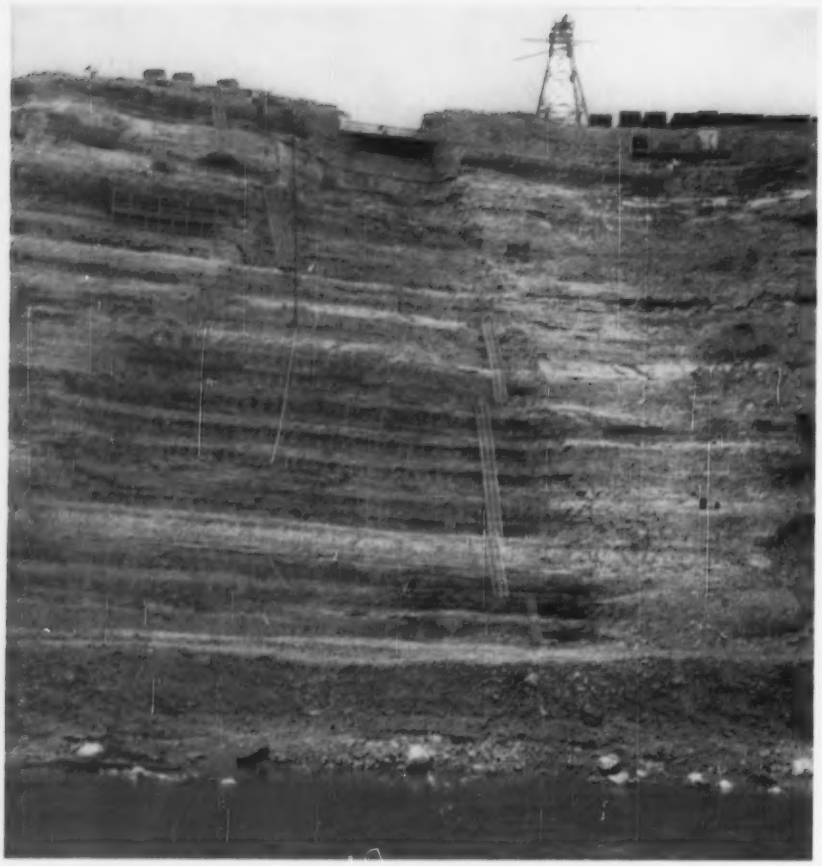
Drilling holes for blasting is done with Ingersoll-Rand T-3500's with 3¼-in. hammers equipped with 2¾-in. carset bits. A 123J drill is also used with a Gardner-Denver Air-Trac mount. Three of these Air-Tracs are in service and, in combination with the drill units, are found to be highly portable. With this equipment, two men can readily drill 400 ft. of holes in an 8-hr. shift.

The blast holes are drilled on a staggered pattern, with each hole 20 to 24 ft. deep, 2¾ in. in diameter, spaced on 12 to 14-ft. centers. The burden on each hole averages 6 to 7 ft. They are loaded with 2-in.-diameter cartridges of 40 per cent dynamite on an explosives loading ratio of 0.5 lb. of dynamite for each 1 cu. yd. of rock in place. Detonation is accomplished with short-period delay electric blasting caps ranging from first to 14th periods of delay. A minimum of secondary blasting is required.

In some of the quarry areas, seams of clay 50 ft. deep and from 5 to 20 ft. wide are encountered all the way down the slope. This condition necessitates blasting up to a clay seam, removing the clay carefully, and then resuming normal drilling and blasting procedures. Occasionally, the drill operators strike small caverns or pockets from 1½ to 2 ft. in diameter. When this occurs, they drill down to the pocket, load a charge of dynamite, fill the cavity with clay stemming, and detonate the charge.

The rock blasted in the quarry is excavated with a 2½-cu. yd. Bucyrus-Erie 54-B power shovel and loaded into Euclid 36-TD end-dump trucks for short hauls to the crusher chute.

The contract specifications do not permit blasting against rock formations that will form the final surfaces on or against which concrete is to be placed. Local pockets of weathered rock or



TERRACED KEYWAY: This view of the terraced keyway on the right bank shows one of the tail towers and a shuttle-track bridge at the top of the bluff.

CONSTRUCTION SUPERVISORS: Front, left to right: H. C. Thornack, labor coordinator; and Harold I. Maxwell, general superintendent. Rear, left to right: B. E. Wright, general maintenance; J. H. Poynter, equipment superintendent; John Logan, excavation superintendent; and Art Campbell, project manager.

clay encountered during construction operations must be removed and the pockets backfilled with concrete.

In excavating for the stilling basin, a typical blast involves drilling holes 2¼ in. in diameter, 21 ft. deep, with 6 by 8-ft. spacings. The holes are loaded with 40 per cent dynamite and detonated with short-period delay electric blasting caps, zero to 7th periods of delay.

In the excavation for the steps of the north foundation, one blast involved the detonation of 960 holes loaded with 40 per cent dynamite, primed with short-period delay caps, zero through 7th delay, and fired with a Hercules blasting machine.

Processing the Aggregate

From the primary surge pile at the Baird Mountain quarry to the secondary pile near the mixing plant more than one mile distant, the aggregate is transported by belt conveyor. On the way it is passed through a scrubbing station. After further crushing and screening, it is stored in four large aggregate silos. Here an interesting phase of the job is the Morrison-Knudsen method for precooling the aggregate by circulating cold air (40 degrees F.) through the tanks. The air-cooling is achieved by blowing it over a series of coils cooled by a battery of ammonia compressors. By this means, the aggregate is brought down from normal temperatures, according to the season, to 40-45 degrees. When water chilled to 32 degrees is added in the mixing cylinders, the concrete can be poured into the forms at about 50 degrees, even in midsummer. This, of course, is another precautionary measure to assure that there will be no cracks and leakage in the dam caused by the concrete contracting as it hardens.

Air for the quarry equipment is supplied by Ingersoll-Rand 600 rotary compressors; for excavation and the stationary air plant, by Gardner-Denver Model WJD's.

A shuttle-line track along the top of the bluff runs directly under and through the mixing plant, from which concrete is loaded into 4-cu. yd. and 8-cu. yd. buckets, one full bucket to a car. The cars are moved by diesel electric motors along the track for about

¼ mile upstream, where the buckets are hoisted onto cable lines stretched between 200-ft. track-mounted tail towers on that side of the river, and a 430-ft. head tower on the opposite side, near where the keyway of the dam is laid.

One large cable line is a track for the 8-cu. yd. buckets carrying concrete to the dam proper. The smaller, attached to the second tail tower, carries 4-cu. yd. buckets to the stilling basin and other locations where the smaller loads are more convenient to drop.

TV Does a Job

One of the most unusual features of the project, from a contractor's standpoint, is the use of television for the concrete pouring. There is nothing new, of course, in two-way radio communication on large construction projects. But, according to Roger Evans, first project manager at Table Rock Dam, this is the first time the Morrison-Knudsen Company has used television for that purpose.

Close by the cable-line terminals is a control tower equipped with remote-hoisting engine controls, high-frequency two-way radio, and a television set. The TV receiver is channeled to a transmitter inside the engine room at the base of the tall head tower across the river. This transmitter is pointed at two windlasses in the engine room, one for horizontal pulling along the cable line, and the other for lowering and raising the concrete buckets.

The operator in the control tower is near enough to see by direct vision how to hoist a loaded bucket from car to cable, or to return the empty bucket. To save time, he starts lowering the loaded bucket on the cableway as soon as it is suspended over the river, which means there is horizontal and vertical motion at the same time. His TV screen now shows one windlass moving.

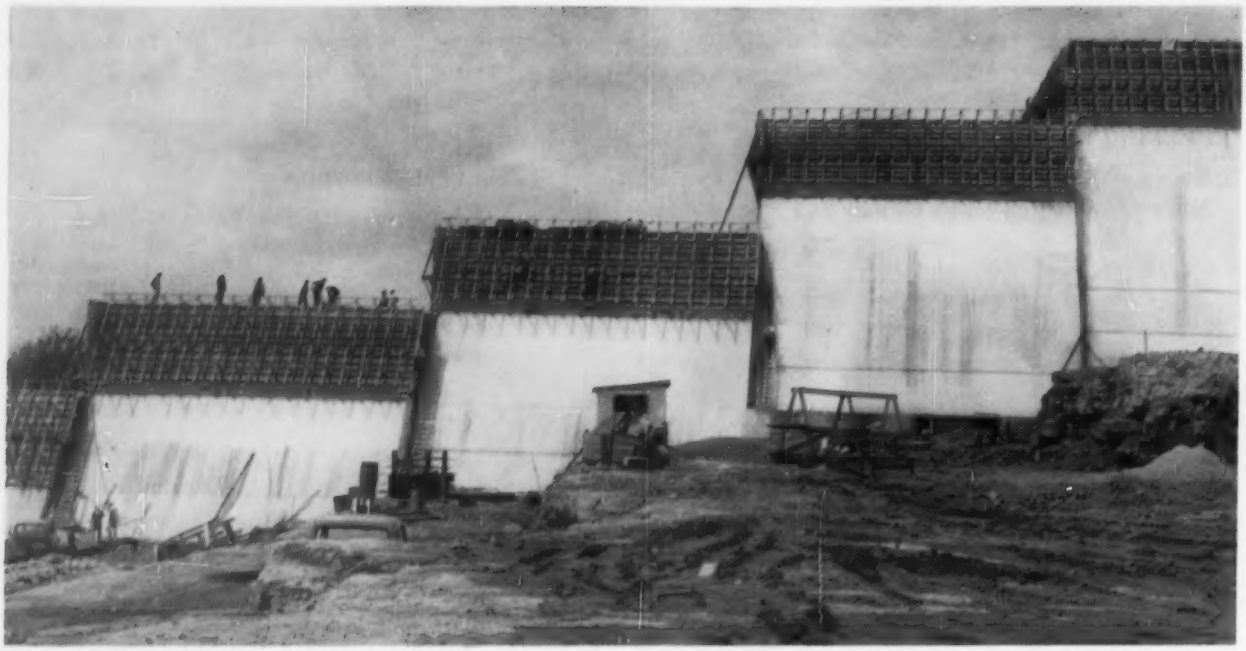
As the bucket nears the dump point, the control operator is in radio communication with a ground bellman who directs him as to the exact placing and lowering of the load. For this purpose, both conversation and sound signals are used. The principal advantage of the TV facility is that the control operator can see at any moment, merely by glancing at his screen, when either windlass is moving, or has come to a complete stop. This avoids the hazard of reversing the mechanism while still in motion, which could strip gears in the hoisting engine.

The television reception varies somewhat according to weather conditions, but it is usually good, both during the day and the night. Construction operations are around the clock six days a week, with three shifts each day. By using TV, only about 3½ minutes are required to transport a 16-ton bucket of concrete for the 2,600-ft. length of maximum haul and return it empty. In addition to speedier operation, the full time of only one man on each shift is required. Estimates indicate that the saving on this project through the use of TV communications will amount to approximately $140,000.

Equipment, Safety, Personnel

The dirt-moving equipment includes one P&H Sierra loader, seven D-8 Cat tractors, two TD-24's, one TD-9, one DW-20, two 50-ton Southwest rollers, four Wooldridge Cobras, and two Adam 660 graders. Other equipment not previously mentioned consists of one Model 111 Marion combination,

LEFT BANK FOUNDATION: Concrete for the left bank foundation is delivered to the site in 8-cu. yd. buckets via overhead cable lines.



FOUNDATION BLOCKS: This view from downstream shows part of the left-wing lower foundation blocks of the dam. Rising terraces in the rock are apparent in the foreground.

REMOTE CONTROL: From this tower equipped with remote-hoisting engine controls, a high-frequency two-way radio, and a television set, the operator controls the hoisting of buckets loaded with concrete and the return of empty buckets.

one Northwest-6 combination, 13 Euclid TD-36 trucks, and 10 bottom-dump Euclids.

As of July 30, 1955, the contractor's payroll listed 648 hourly workers and 73 salaried employes. Art Campbell is the project manager of the joint venture, a post in which he succeeded Roger Evans who was in charge of operations from the start of work on November 16, 1954, until the following June.

In line with established Morrison-Knudsen policy, a well-organized safety program is in effect. Ed Maloney, safety supervisor, holds safety meetings several times a week. Each group of employes has an alternating safety committee member who serves for a two-week period. Up to August 8, no loss of time from accidents had been experienced by the quarry division, and on the entire project only nine lost-time injuries had occurred in nine months.

In addition to Project Manager Art Campbell, the supervisory force at the Table Rock Dam includes Harold I. Maxwell, general superintendent; C. W. Bolton, project engineer; and Dennis Lucy, office manager. John Logan is excavation superintendent and Jack Merritt is general foreman on the drilling and blasting operations.

AT LABUCO MINE: Dempsey Sparks, superintendent of Alabama By-Products Corporation's Labuco mine, accepts the Sentinels of Safety trophy and flag at the award ceremony.

Miners And Quarrymen Awarded Top Safety Honors

Presentations of Sentinels of Safety trophies and flags highlight colorful ceremonies at Labuco mine in Alabama and Thornton quarry in Illinois

AUGUST 31, 1955, was a gala day for the employes of Labuco mine of Alabama By-Products Corporation at Flat Creek, Walker County, Alabama. At a barbecue luncheon, the miners and their families, officials of the company, the town, the State of Alabama, and Government representatives celebrated Labuco mine's winning first place in the bituminous-coal group in the National Safety Competition. Labuco's record of 109,955 man-hours of operations underground without a lost-time accident was the best among the 93 bituminous-coal mines enrolled in the 1954 competition.

In his welcoming remarks, P. H. Neal, president of Alabama By-Products Corporation, extended sincere congratulations to the miners from everyone in the organization. He paid special tribute to the "unselfish devotion of the splendid men who work at Labuco mine."

Following Mr. Neal at the speaker's stand were William Mitch, president, District 20, United Mine Workers of America; Honorable George Huddleston, Jr., member of Congress, 9th District, Jefferson County, Alabama; and H. T. Williams, chief of Safety and Inspection Division, Department of Industrial Relations, State of Alabama.

Individual Certificates of Achievement in Safety were presented to the Labuco mine employes by H. J. Sloman, representing the U. S. Bureau of Mines, donor of the certificates. Henry Nelson, president of Local No. 5831, U.M.W.A., received the certificates on behalf of the Labuco miners.

Milton McCall, supervisor of District D, U. S. Bureau of Mines, presented a Certificate of Achievement in Safety to the Thermal mine of Alabama By-Products Corporation for having worked 93,195 man-hours during 1954 without a disabling injury. Thomas Hall, superintendent of Thermal mine, received the certificate.

The final event of the program was the presentation of the bronze Sentinels of Safety trophy and green-and-white safety flag to Dempsey Sparks, superintendent of Labuco mine.

In presenting the awards, J. I. Horty, editor of THE EXPLOSIVES ENGINEER, the donor of the trophy and flag, said, "Your winning top honors in this nationwide safety contest shows clearly that Alabama By-Products Corporation has a carefully planned safety program and that each man at Labuco mine cooperated to make it work. That's the kind of teamwork that pays big dividends in health and happiness to you, your families, your mine associates, and your friends."

At Thornton Quarry

Thornton quarry of Material Service Corporation, a newcomer to the ranks of participants in the National Safety Competition, was honored at a colorful ceremony last September 24. The quarry was enrolled in the nationwide contest for the first time in 1954 and

AT THORNTON QUARRY: Participating in the presentation ceremony at Thornton quarry were, left to right, David L. Arm of the National Safety Council; Thomas E. Miller, representing The Explosives Engineer; George Lenzi, vice president in charge of operations for Material Service Corporation; Edward Schwartz, superintendent of Thornton quarry; Lester Crown, vice president of Material Service Corporation; and Eugene Quenon, chief of District H, U. S. Bureau of Mines.

attained a perfect safety record during 457,570 man-hours of work. Thornton's record topped the records of the other 234 operations enrolled in the quarry group.

Arvid Tienson, safety director for Material Service Corporation, presided at the awards ceremony, which was held at the Brown Derby Amusement Park in Thornton, Illinois.

Over one hundred employes of Thornton quarry, company officials, representatives of the United States Bureau of Mines, the National Safety Council, the Greater Chicago Safety Council, and town officials witnessed the presentation of the trophy and flag by Thomas E. Miller, representing THE EXPLOSIVES ENGINEER.

In presenting the trophy and flag to George Lenzi, vice president in charge of operations for Material Service Corporation, Mr. Miller said, "Your feat in winning top honors in the National Safety Competition is the more remarkable because you won the award the first year you were entered in the contest." In accepting the awards, Mr. Lenzi complimented Edward Schwartz, superintendent of the 1200-acre quarry, for the splendid record made by him and his quarry associates.

Individual Certificates of Achievement in Safety, provided by the United States Bureau of Mines, were presented to the employes by Eugene Quenon, chief of the Health and Safety Division of District H, U. S. Bureau of Mines.

David L. Arm, of the Industrial Section of the National Safety Council, presented The Award of Honor, the council's highest safety award, to the quarry. The Greater Chicago Safety Council, represented at the ceremony by Joseph Stech, presented a plaque to Thornton quarry's superintendent, Edward Schwartz.

Lester Crown, vice president of Material Service Corporation, expressed the gratification of the management personnel with the safety awards won by the Thornton quarrymen. In his remarks he said that the company has always stressed safety in all of its operations, and, in 1954, an all-out drive in the cause of safety was made. "The awards presented to Thornton quarry today are symbols of the safety achievement we have been striving for," Mr. Crown concluded.

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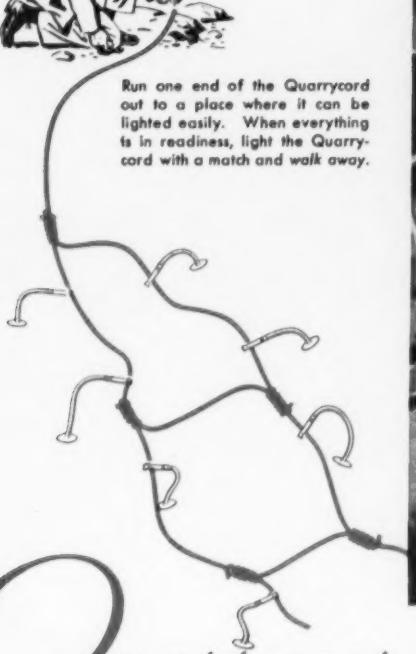

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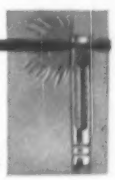

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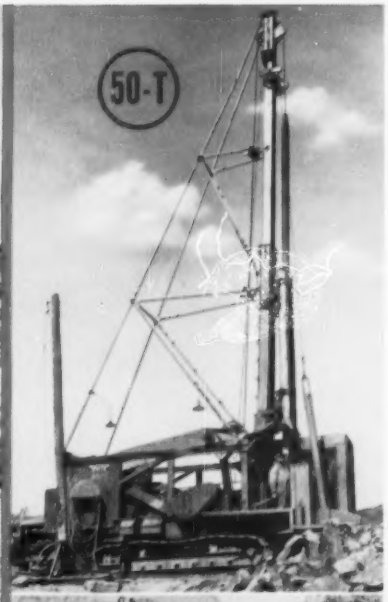

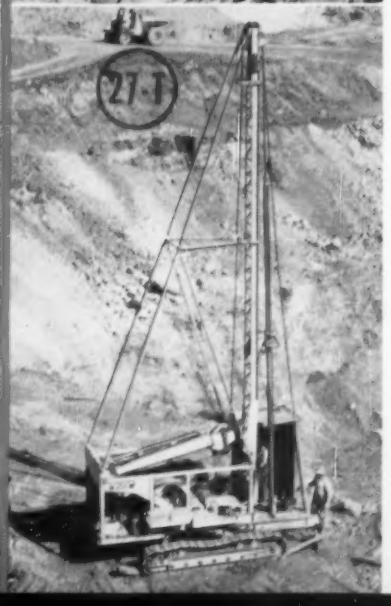

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